The Effect of PhET Simulations on Graphing Linear Equations Among 8th Grade Learners

Edison B. Lopez, Melanie G. Gurat

Saint Mary's University, School of Graduate Studies, Bayombong, Nueva Vizcaya, Philippines

DOI: https://dx.doi.org/10.47772/IJRISS.2024.803209S

Received: 09 July 2024; Revised: 16 July 2024; Accepted: 20 July 2024; Published: 26 August 2024

ABSTRACT

This study assessed the mastery of graphing linear equations among Grade 8 students using PhET simulations to address numeracy challenges. Students from a public high school in Nueva Vizcaya, Philippines, participated in the study. The control and experimental groups were assigned to two different sections. Employing a quasi-experimental pretest-posttest control group design, descriptive statistics (including frequencies, percentages, means, and standard deviations) were used to measure the students' mastery levels. A paired-sample t-test was used to compare pretest and posttest results within each group, while an independent-sample t-test assessed significant differences in gain scores between groups. Results showed improved mastery of graphing linear equations after the interventions, with both groups exhibiting higher posttest mastery levels than pretest levels. Additionally, the experimental group displayed greater improvement. Hence, PhET simulations were found to enhance the learning of graphing linear equations and are recommended for continued use.

Keywords— educational intervention, mastery level, numeracy challenges, mathematics education, quasi-experimental

INTRODUCTION

Mathematical literacy involves individuals' ability to understand, apply, and interpret mathematics across various situations, encompassing skills like problem-solving, communication, reasoning, connection, and representation [20]. It is crucial to cultivate literacy among students as it equips them to think critically and solve problems effectively in real-world scenarios [29]. Teachers play a crucial role in cultivating students' mathematical literacy abilities by presenting concepts in real-world scenarios and assisting students in understanding the abstract language of mathematics [14].

International assessments such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) have been instrumental in propelling school mathematics curriculum reforms. PISA provides valuable insights for policymakers and educators into the effectiveness of the education system and areas needing enhancement. Meanwhile, TIMSS evaluates math and science achievements among fourth and eighth-grade students [18]. The Philippines enacted Republic Act No. 10533 (K to 12 Act), the Enhanced Education Act, aiming to enhance the country's basic education system by reinforcing the curriculum and extending the duration of basic education from ten to twelve years. The K to 12 program equips graduates with 21st-century skills (1. Information, media, and technology skills; 2. Learning and innovation skills; 3. Communication skills; and 4. Life and career skills) integrated into the curriculum, allowing practical application across diverse fields and preparing them for multiple pathways post-education [9]. In connection to mathematics literacy, DepEd Curriculum Guide [7] stated that Mathematics is a skills-based subject that encompasses quantities, shapes, figures, functions, logic, and reasoning, serving as both a tool of science and a language with its notations and symbols, enabling effective expression of concepts and

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS July 2024 | Special Issue on Education

ideas. In particular, its contents were Numbers and Number Sense, Measurement, Geometry, Patterns and algebra, and Statistics and Probability.

Despite these initiatives, the Philippines struggled with low mathematics scores in international assessments [32]. The Philippines' participation in TIMSS in 2003 and 2008 yielded scores of 378 and 355, respectively [2][17], indicating a decline in performance over those years, revealing a gap which indicates that there is a gap in numeracy during those years. PISA 2018 results revealed that the Philippines landed second to last in Mathematics among 79 participating countries. This may be attributed to different predictors such as student factors, family factors, teacher factors, classroom and school factors, and policy factors, as revealed by several researchers [16].

The coronavirus further heightened educational challenges in 2020, prompting the Basic Education Learning Continuity Plan to ensure continued learning despite the pandemic [8]. The department continued to exert efforts to address the challenges in education until the implementation of full face-to-face classes in November 2022. In fact, Vice President and Education Secretary Sara Z. Duterte launched MATATAG: Bansang Makabata, Batang Makabansa, to establish the agency's and stakeholders' new direction in addressing basic education challenges [21].

While there was a slight improvement in mathematics scores from 2018 to 2022, the Philippines still lagged, scoring below the OECD average [23][1]. This was evident in the international assessment and the National Achievement Test (NAT) in Mathematics [10]. Moreover, Region 02 (Cagayan Valley) exhibited the lowest mean percentage score in the 2019 math NAT for Grades 6, 10, and 12, particularly struggling with items that promote problem-solving and critical thinking in science process skills [10].

Addressing these challenges requires innovative teaching methodologies such as PhET simulations, encompassing a series of research-based interactive computer simulations meticulously crafted to enhance the instruction and comprehension of multiple subjects, encompassing physics, chemistry, mathematics, and various scientific disciplines [31]. These are crafted based on design principles aimed at fostering student engagement in science and mathematics through inquiry by encouraging scientific exploration, interactivity, revealing the unseen, visualizing mental models, offering diverse representations (such as object motion, graphs, numbers), establishing real- world connections, providing implicit guidance for productive exploration, and ensuring adaptability across various educational contexts [26].

Several studies, both local [4][24][34] and international [3][35][25], have proven its significant effect on the student's performance specifically in science-related subjects. Some PhET simulations are math-related, but only a few study its effect on this subject.

With this, the study aimed to explore the effect of utilizing PhET simulations on the mastery levels of 8th graders in Mathematics. Specifically, it sought to answer the following questions:

1. What is the mastery level of the control and experimental groups before and after utilizing the PhET simulation in teaching Graphing Linear Equations?;
2. Is there a significant difference between the pretest and posttest scores of the control and experimental group?; and
3. Is there a significant difference between the gain scores of the control and experimental groups?

METHODOLOGY

Research Design

This study employed a quasi-experimental approach, particularly pretest-posttest control group design. Two groups, experimental and control, were randomly assigned. The independent variables included the use of PhET simulations in teaching graphing linear equations (X) and the existing teaching method C. Meanwhile, the dependent variables were the students' mastery levels before and after the interventions (O_1, O_2).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS July 2024 | Special Issue on Education

Treatment Group	M	O_1	X	O_2
Control Group	M	O_1	C	O_2

Fig. 1. The pretest-posttest control group design

Research Environment and Participants

The study was conducted at Bonfal National High School, Bonfal Proper, Bayombong, Nueva Vizcaya, Philippines, during the first quarter of the School Year 2023-2024. It involved two Grade 8 sections with math classes scheduled in the morning, taught by the same teacher. The study involved 70 Grade 8 learners from different sections of the same school. Of these, 36 students from Section A were assigned to the experimental group, while 34 students from Section B were assigned to the control group. To ensure comparability between the groups before the intervention, an independent sample t-test was conducted on the pretest scores. Results revealed no significant differences between the control group (M = 21.11, SD = 13.04) and experimental group (M = 25.59, SD = 13.30) at a 0.05 significance level, $t = -1.422$, $p > .05$. This finding indicates that prior to the experiment, both groups exhibited similar levels of concept mastery in graphing linear equations, making them comparable as illustrated in Table 1.

Table 1. T-test for independent samples result in comparing the pretests of control and experimental group

Pretest	Mean	SD	t	df	Sig. (2-tailed)
Control Group	21.11	13.04	-1.422	68	.160
Experimental Group	25.59	13.30			

Instrumentation

The study utilized a mastery test comprising multiple choice items adapted from the Department of Education's Quarter 1 – Module 10: Graphing Linear Equations in Mathematics 8. Learning resources from the Department of Education undergo rigorous quality assurance procedures [13]. The test included ten items aligned with the competency code M8AL-If-2 on graphing linear equations. The mastery test undergone reliability and validity testing. Results of the evaluation show a Cronbach's alpha of 0.90 which is highly reliable [33] and Content Validity Index (CVI) value of 0.92 which is an acceptable value [12].

Identical tests were administered before and after the intervention, although the order of the items was not retained.

Data Treatment

Descriptive statistics were used to present the gathered data, including frequencies, percentages, means, and standard deviations. A scoring system was used to assess students' responses: 0 point for incorrect answers and 1 point for correct ones, totalling up to 10 points.

Table 2 outlines the qualitative scale descriptions on evaluating student scores on their post-test, adapted from DepEd Memorandum No. 160, s. 2012

Table 2. Student mastery level using mean percentage score (MPS) from Department of Education

Mean Percent Score (MPS)	Descriptive Equivalent
96-100%	Mastered
86-95%	Closely Approximating Mastery
66-85%	Moving Towards Mastery
35-65%	Average
15-34%	Low

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS July 2024 | Special Issue on Education

5-14%	Very Low
0-4%	Absolutely No Mastery

By the Central Limit Theorem (CLT), the data is assumed to be normally distributed since n>30 for both control (n=36) and experimental group (n=34). The CLT posits that as sample sizes increase, the distribution of sample means converges to a normal distribution, irrespective of the population's distribution, with sample sizes of 30 or more commonly regarded as satisfactory for the CLT to be applicable [11].

With this, a paired sample t-test was employed to analyze the significant difference between the pretest and post-test results within both the control and experimental groups. Moreover, t-test for independent samples was utilized to assess the significant difference between the gain scores of the control and experimental groups. Gain score is the difference between the post test score and the pretest score.

Data Gathering Procedures

The study comprised three main phases: pre-experimental activities, the experiment, and post-experimental activities. In the first phase, the control and experimental groups underwent a pretest before any intervention. The second phase involved implementing the teaching strategies: the control group received the existing method (lecture method), while the experimental group experienced the integration of PhET simulations. The third and final phase encompassed administering the posttest to both groups after the teaching interventions.

RESULTS AND DISCUSSIONS

Mastery Level of the Control and Experimental Groups Before and After the Intervention

Table 3 presents the frequency, percent, mean, and standard deviation of the mastery level on graphing linear equations of the control and experimental group before and after using PhET simulations.

Table 3. Descriptive statistics on the mastery level on graphing linear equations of the control and experimental group before and after the intervention

Mastery Level	**Control Group**				**Experimental Group**			
	Pretest		Posttest		Pretest		Posttest	
	f	%	f	%	f	%	f	%
Mastered	0	0.00	0	0.00	0	0.00	0	0.00
Closely Approximating Mastery	0	0.00	0	0.00	0	0.00	0	0.00
Moving Towards Mastery	0	0.00	1	2.78	0	0.00	2	5.88
Average (A)	5	13.89	14	38.89	10	29.41	24	70.59
Low (L)	18	50.00	16	44.44	15	44.12	8	23.53
Very Low	9	25.00	2	5.56	8	23.53	0	0.00
Absolutely No Mastery	4	11.11	3	8.33	1	2.94	0	0.00
TOTAL	**36**	**100**	**36**	**100**	**34**	**100**	**34**	**100**
MPS	21.11		31.94		25.59		45.00	
Mastery Level	L		L		L		A	
SD	13.04		15.46		13.30		12.85	

Legend: A-Average Level (35-65%), L-Low Level (15-34%)

Table 3 shows that in the control group, most students exhibited a ‘low’ level of mastery during their pretest (50.00%) and posttest (44.44%), indicating that the topic was challenging to students. Notably, a slight discrepancy of 5.55% is observed between the 'average' and 'low' mastery levels, accompanied by the progression of one student into the 'moving towards mastery' level (2.78%), signifying progress.

In contrast, the experimental group initially began mostly at a 'low' level (44.12%) during the pretest. However, by the posttest, the majority had advanced towards an 'average' mastery level (70.59%), indicating a grasp of the basics of Graphing Linear Equations wherein they can solve simple problems but might struggle with harder ones. Importantly, the progress goes beyond mere averages, with two subjects achieving the 'moving towards mastery' level (5.88%), indicating higher score beyond the 'average' level. These subjects are learning and starting to understand more about Graphing Linear Equations.

Furthermore, averaging across both groups, the mastery level in the posttest consistently exceeded that of the pretest. However, while the scores improved for the control group, they remained in the “low mastery” category. Conversely, the PhET simulation-integrated facilitated a shift from ‘low’ to ‘average level’ mastery. This suggests an improvement in the mastery level of the students in utilizing PhET simulations as intervention in understanding Graphing Linear Equations.

In consonance to this, the study conducted by several researchers found out that PhET simulation-based learning improve students’ understanding of concepts, increase motivation levels therefore improving academic achievement [3][15][30].

Nevertheless, despite the improvements, the average still ranges from ‘average’ to low. This underscores the need for continued enhancement strategies. Tailoring interventions to address specific areas or topics where mastery remains low could be instrumental in further elevating the overall mastery levels.

One plausible explanation for these findings could align with the study conducted by [5], which highlighted students' negative attitudes and perceptions towards mathematics.

Difference Between the Pretest and Posttest Results of the Control and Experimental Group

Tables 4 and 5 present the result of paired sample t-test comparing the score of the control and experimental group before and after implementing the interventions.

Table 4. Paired sample t-test result in comparing the pretest and posttest results of the control group

	MPS	SD	t	df	Sig. (2-tailed)
Pretest	21.11	13.04	-3.654	35	.001**
Posttest	31.94	15.46			

* Significant at 0.05 level
** Significant at 0.01 level

The data in Table 4 indicates a significant disparity ($t = -3.654$, $p = 0.001 < 0.01$) between the pretest ($MPS = 21.11$, $SD = 13.04$) and posttest ($MPS = 31.94$, $SD = 15.46$) in control group. This suggests that the mastery level for the control group has improved significantly which further indicate that the usual teaching method is effective in understanding the topic.

The underlying reason for this data can be attributed to [19] study which they compared traditional and nontraditional presentation methods in terms of student preference and performance assessment revealed a preference among students for traditional lectures, alongside higher performance in assessments associated with this format.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS July 2024 | Special Issue on Education

Table 5. Paired sample t-test result in comparing the pretest and posttest results of the experimental group

	MPS	SD	t	df	Sig. (2-tailed)
Pretest	25.59	13.30	-7.275	33	.000**
Posttest	45.00	12.85			

* Significant at 0.05 level
** Significant at 0.01 level

Table 5 displayed a significant difference ($t = -7.275$, $p = 0.000 < 0.01$) between the pretest ($MPS = 25.59$, $SD = 13.30$) and posttest ($MPS = 45.00$, $SD = 12.85$) MPS in the experimental group. These results imply that participants showed significantly higher mastery level in their posttest compared to their pretest. This further indicate that the PhET simulation- integrated teaching method is effective in understanding graphing linear equations.

In line with this, the simulations were also discovered to significantly improve students' mathematical understanding of fractions [28]. In contrast, [22] found that the control group exhibited no significant differences in pre- and post-test scores.

Difference Between the Gain Scores of the Control and Experimental Groups

Table 6 presents the result of t-test for independent samples comparing the gain score of the control and the experimental groups.

Table 6. T-test for independent samples result in comparing the gain score of control and experimental group

	Mean	SD	t	df	Sig. (2-tailed)
Control Group	10.83	17.79	-2.142	68	.036*
Experimental Group	19.41	15.56			

* Significant at 0.05 level

Table 6 reveals a significant difference ($t = -2.142 p = 0.036 < 0.05$) in the gain scores between the control and experimental groups. Both groups showed improvement, but the data indicate a greater enhancement in the experimental group compared to the control group. This suggests that the intervention was more effective in graphing linear equations compared to the the usual teaching method.

This finding is in support with [27]'s study, which observed that students using PhET simulations obtained significantly higher scores compared to the group without any tools. Additionally, it was noted to have a remarkable impact on learning [6].

CONCLUSIONS

The mastery level of students in utilizing PhET simulation as an intervention improved in understanding graphing linear equations. This suggests that the intervention effectively enhances students' understanding of the lesson.

In both groups, students performed better in posttests compared to the pretests. This shows that regardless of the methods used, students showed learning progression and assimilation of knowledge.

The experimental group had a higher improvement in the mastery level compared to the control group. This suggests that the usage of PhET simulations has a better impact in terms of students' mastery in mathematics topics than the traditional approach to teaching.

RECOMMENDATIONS

Based on the favorable mastery ratings achieved by students using PhET simulations, it's advisable to consistently integrate these simulations into graphing linear equations topics. Prioritizing active student engagement through guided activities is crucial for maximizing intervention effectiveness, alongside gathering feedback for tailored instruction. Exploring diverse methods of incorporating PhET, like in-class demonstrations or group activities, can significantly enhance student exposure and comprehension of the topic.

The observed mastery level progress in both PhET-integrated and usual teaching methods warrants further comparative analysis. Continuing assessment and comparison of student outcomes between these approaches offer valuable insights into their effectiveness. Blending successful elements from both methods can optimize learning outcomes for a diverse student range.

This study underscores the impact of PhET simulations on students' mastery of Graphing Linear Equations. Administrators should provide educators with training and resources to effectively integrate PhET simulations into teaching methodologies. Longitudinal studies observing how PhET-taught students perform in higher-level math courses would evidence the long-term impact of simulation-based learning on math proficiency. Establishing a platform for educators to share successful strategies with PhET simulations in teaching graphing linear equations is also essential.

REFERENCES

1. Acido, J. V. & Caballes, D. G. (2023). Assessing educational progress: A comparative analysis of PISA results (2018 vs. 2022) and HDI correlation in the Philippines. International Journal of Novel Research and Development, 8(12). https://www.ijnrd.org/papers/IJNRD2312395.pdf
2. Arora A., Foy, P., Martin, M. O., & Mullis, I. V. S. (2009). TIMSS advanced 2008 technical report. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.
3. Banda, H. J., & Nzabahimana, J. (2022). The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement Among Malawian Physics Students. Journal of Science Education and Technology, 32(1), 127-141. https://doi.org/10.1007/s10956-022-10010-3
4. Buday, B. M., Dalisay, C. M. C., Emralino, B. S., Laurio, S. L. R. (2023). Exploring students' motivation and academic performance in learning ohm's law using phet simulations. World Journal of Advanced Research and Reviews, 20(02), 287–294. https://doi.org/10.30574/wjarr.2023.20.2.2232
5. Chand, S., Chaudhary, K., Prasad, A. & Chand, V. (2021). Perceived causes of students' poor performance in mathematics: A case study at Ba and Tavua Secondary Schools. Frontiers in Advanced Mathematics and Statistics, 7(614408). https://doi.org/10.3389/fams.2021.614408
6. Cherif Alaoui Mrani, Abdelkrim El hajjami, & Khalid El khattabi. (2020). Effects of the Integration of PhET Simulations in the Teaching and Learning of the Physical Sciences of Common Core (Morocco). Universal Journal of Educational Research 8(7), 3014-3025. https://doi.org/10.13189/UJER.2020.080730
7. Department of Education. (2013).K to 12 Curriculum Guide - Mathematics. http://www.deped.gov.ph/wp-content/uploads/2019/01/Math-CG_with-tagged-math-equipment.pdf
8. Department of Education Order No. 12 (2022). Policy guidelines for the provision of learning resources and needed devices and equipment and funding relevant activities for the implementation of basic education-learning continuity plan. https://www.deped.gov.ph/wp-content/uploads/2022/03/DO_s2022_012.pdf
9. Department of Education Order No. 21 (2019). Policy guidelines on the K to 12 Basic Education Program. https://www.deped.gov.ph/wp-content/uploads/2019/08/DO_s2019_021.pdf
10. Department of Education Regional Office 02 (2019). 2018 National achievement test (NAT) 6, 10, & 12 results and analysis. https://region2.deped.gov.ph/wp-content/uploads/2019/05/2018-NATIONAL-ACHIEVEMENT-TEST-NAT-610-12- RESULTS-AND-ANALYSIS-.pdf

11. Ganti, A. (2024). Central Limit Theorem (CLT): Definition and key characteristics. Investopedia. https://www.investopedia.com/terms/c/central_limit_theorem.asp
12. Gilbert, G. E., & Prion, S. (2016). Making sense of methods and measurement: Lawshe's content validity index. Clinical simulation in nursing, 12(12), 530-531. https://doi.org/10.1016/j.ecns.2016.08.002
13. Hernando-Malipot, M. (2020, September 26). DepEd says learning materials for public schools undergo quality assurance. Manila Bulletin. https://mb.com.ph/2020/09/25/deped- says-learning-materials-for-public-schools-undergo-quality-assurance/
14. Istiandaru, A., Prasetyo, P. W., & Istihapsari, V. (2021). Mathematics literacy skills in pre-service teachers: What could they do? Bulletin of Applied Mathematics and Mathematics Education 1(1), 31-38. https://doi.org/10.12928/BAMME.V1I1.3830
15. Itsnaini Rahmita, F., & Wasis, W. (2022). Remediasi Miskonsepsi dengan LKPD Model Guided Inquiry Learning Berbantuan PhET Simulation pada Materi Fluida Dinamis. Jurnal Ilmiah Pendidikan Fisika 6 (2). https://doi.org/10.20527/jipf.v6i2.5276
16. Maamin, M.; Maat, S.M.; H. Iksan, Z. (2022). The influence of student engagement on mathematical achievement among secondary school students. Mathematics 2022, 10(41). https://doi.org/10.3390/math10010041
17. Mullis, I. V. S., Martin, M. O., Gonzalez, E. J. & Chrostowski, S. J. (2004). TIMSS 2003 international mathematics report. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College
18. Kadijevich, D.M., Stephens, M., Solares-Rojas, A., Guberman, R. (2023). Impacts of TIMSS and PISA on Mathematics Curriculum Reforms. In: Shimizu, Y., Vithal, R. (eds) Mathematics Curriculum Reforms Around the World. New ICMI Study Series. Springer, Cham. https://doi.org/10.1007/978-3-031-13548-4_22
19. Martirosov A.L., Alex J., Doane A., Patel R., Aprilliano B., Kale-Pradhan P. (2023) Podcasts and videos and slides. . .oh my!: Traditional vs. nontraditional teaching methods in remote settings. Currents in Pharmacy Teaching and Learning 15(6), 587-592. https://doi.org/10.1016/j.cptl.2023.06.007
20. Maslihah, S., Waluya, S. B., Rochmad, & Suyitno, A. (2020). The role of mathematical literacy to improve high order thinking skills. Journal of Physics: Conference Series, 1539(1). https://doi.org/10.1088/1742-6596/1539/1/012085
21. MATATAG: DepEd's new agenda to resolve basic education woes. (2023, January 30). Deped.gov.ph. https://www.deped.gov.ph/2023/01/30/matatag-depeds-new-agenda-to-resolve- basic-education-woes/
22. Mohd Najib, M. N., Md-Ali, R., & Yaacob, A. (2022). Effects of Phet Interactive Simulation Activities on Secondary School Students' Physics Achievement. Jurnal Ilmiah Pendidikan Fisika 3(2), 302-312. 10.48165/sajssh.2022.3204
23. OECD (2023). PISA 2022 results: Factsheets – Philippines. https://www.oecd.org/publication/pisa-2022-results/webbooks/dynamic/pisa- country-notes/a0882a2d/pdf/philippines.pdf
24. Omoy, E. Q. (2023). PhET interactive simulations: A tool in improving academic performance of grade 10 students in balancing chemical equations. International Scientific Research and Researchers Association, (18)1, 1-11. https://ijfscfrtjournal.isrra.org/index.php/Formal_Sciences_Journal/article/view/746/84
25. Özcan, H., Çetin, G. & Koştur, H. I. (2020). The Effect of PhET Simulation-based Instruction on 6th Grade Students' Achievement Regarding the Concept of Greenhouse Gas. Science Education International, 31(4), 348-355. https://doi.org/10.33828/sei.v31.i4.3
26. PhET (2023). About PhET. https://phet.colorado.edu/en/about
27. Pranata, O. D. (2023). Physics Education Technology (PhET) as Confirmatory Tools in Learning Physics. Jurnal Riset Fisika Edukasi Dan Sains, 10(1), 29–35. https://doi.org/10.22202/jrfes.2023.v10i1. 6815
28. Rahmawati, Y., Zulhipri, Hartanto, O. Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET interactive simulations. Journal of Technology and Science Education, 12(2), 303-326. https://doi.org/10.3926/jotse.1597

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS July 2024 | Special Issue on Education

29. Rojas, E., Benakli, N. (2020). Mathematical Literacy and Critical Thinking. In: But, J. (eds) Teaching College-Level Disciplinary Literacy. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-39804-0_8
30. Samitra, D., Firdaus, M. L., & Krisnawati, Y. (2023). Physics Education Technology Project (PhET): Interactive Simulation to Improve Students' Understanding of Concepts and Perceptions. Jurnal Penelitian dan Pengembangan Pendidikan, 10(3), 646-654. https://doi.org/10.33394/jp.v10i3.7879
31. Science Education Resource Center (SERC) (2023). What is PhET? https://serc.carleton.edu/sp/library/phet/what.html
32. Servallos, N. J. (2023, December 07). PISA: Philippines 5 to 6 years behind. The Philippine Star. https://www.philstar.com/headlines/2023/12/07/2317044/pisa-philippines-5-6- years-behind
33. Streiner, D. (2003) Starting at the Beginning: An Introduction to Coefficient Alpha and Internal Consistency. Journal of Personality Assessment, 80, 99-103. https://doi.org/10.1207/S15327752JPA8001_18
34. Taneo, L. E. & Moleño, R. E. (2021). Students’ performance using Physics Education Technology (PhET) interactive simulation strategy. Journal of Education & Social Policy 8(2), 52-55. https://doi.org/10.30845/jesp.v8n2p8
35. Yassin, A. A. B. (2022). The Effect of Using Interactive Simulation (Phet) and Virtual Laboratories (Praxilabs) on Tenth-Grade Students’ Achievement in Physics. Britain International of Linguistics, Arts and Education(BIoLAE) Journal, 4 (2), 58-72 https://doi.org/10.33258/biolae.v4i2.693